Progress towards Sub-micron X-ray Imaging (4-12keV) using Elliptically Bent Mirrors

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INTRODUCTION

The advent of third generation synchrotron sources has required the continued development of x-ray focussing optics in order to utilize the available new source brightness. We describe here progress this year made with grazing incidence optics operating in the 4-12keV range, in particular using the Kirkpatrick-Baez (KB) focussing geometry[1] with a single metal film as the reflector. Our aim is to achieve x-ray spot sizes on the spatial scale of 1:m which are considered useful for various material science problems. The desired elliptical shape of the mirror is produced by the controlled bending of a flat mirror. Such optics offer broad bandpass and can be inexpensive. The origin of this technique and its development to date has been described earlier [2,3].

KIRKPATRICK BAEZ FOCUSSING MIRRORS

In the optical system used the synchrotron source is imaged. The mirror dimensions are defined by the source size, operating wavelength, demagnification and the beamline length. The source size at the ALS is around 30 μm x 300 μm (vertical x horizontal FWHM) and the experiment location (beamline 10.3.2) defines the source to mirror distance to be 30m. With a platinum coating, adequate reflectivity is achieved for up to 12 KeV photons with a mirror grazing angle of 5.8 mrad (0.33°). The maximum convergence of the light onto the sample is limited by this critical angle of reflection of the highest energy required. If a higher convergence angle is used it means that at one end of the mirror light will be traveling almost parallel to the surface and at the other it will be exceeding the critical angle and will not be reflected.

In the vertical plane a demagnification of 60 should achieve a 0.5 μm focus with a mirror to focus distance = 500 mm.. For 12 KeV photons the critical energy reflected from a platinum mirror is about 6 mrad. As this is a prototype mirror we opted for a conservative small convergence angle onto the sample of only 1.9 mrad. Mirror length was thus defined as 163mm and angular acceptance = 31 μrads.

Similar arguments apply to the horizontally focussing mirror. The horizontal beam size is approximately 300 μm and thus a demagnification of 300 will result in a 1 micron sized image with a mirror to focus distance of 100 mm, this being considered a reasonable working distance between this mirror and sample. With this a conservative convergence angle onto the sample of 2.3mrad, a mirror length of 40 mm is defined with a horizontal acceptance of 7.6 μrads.

The ideal mirror shape required for imaging the synchrotron source is that of the surface of an off axis plane ellipse. Such a surface is able to perform true point to point imaging. The desired elliptical surface is produced by the controlled bending of a flat mirror produced by holding the ends of the mirror and applying opposite couples of different magnitude. The width of the mirror is also varied along its length which changes the cross sectional moment. In this way the exact ellipse can in principle be obtained. In practice variations in the initial mirror shape and anticlastic bending all conspire to degrade mirror performance.

The mirror flats used in the benders were flat to sub-micro radian slope errors as measured with a long trace profiler and had around 0.2 nm roughness as measured with a micromap optical profiler. The bending was monitored in the ALS optical metrology laboratory, primarily using a long trace profiler [4] to measure slope as a function of position. Typical rms slope errors from the required ellipse over the middle 140 mm of the vertical focussing mirror are around 1.5 µrad. For the shorter horizontal focussing mirror we measured an rms slope error from the required ellipse over the central 32 mm of 0.6 µrad.

X-RAY PERFORMANCE

We have performed knife edge tests on the KB focus with white light radiation. The knife edge used was a 50-µm Gold coated Tungsten wire. By reducing the mirror acceptance aperture to about 50%, the best horizontal and vertical foci achieved were 1.2 µm and 0.8 µm FWHM respectively.Fig.1 shows the vertical focussed differentiated knife edge scan, showing significant tails to the peak profile. This is consistent with x-ray scattering which is generally considered[5] to arise due to mid spatial frequency errors in the mirror (1mm – 1 µm spatial range) that the Long Trace Profiler is unable to resolve. The next iteration of the micro focus mirrors will require special attention to this mirror specification.

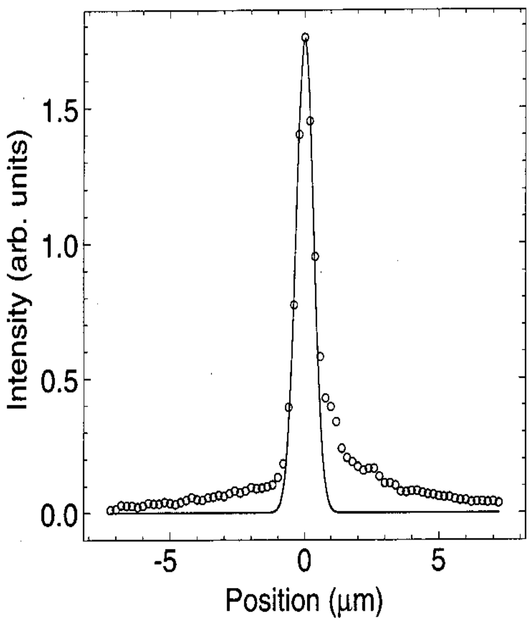

Fig.1. Differentiated knife edge scan in the vertical plane showing the beam profile. FWHM = 0.8 µm, with tails considered to be due to scatter.

ACKNOWLEDGMENTS

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy, under Contract no. DE-AC03-76SF00098.

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